HEV, P-HEV, and EV market 2011-2020

Impact on the battery Business

Christophe PILLOT
Director, AVICENNE ENERGY
AVICENNE PROFILE

Information for Growth - Powering your company’s market strategy with in-depth research

- Creation: 1992
- Headquarter: Paris
- Liaison Office: Japan, USA
- AVICENNE Energy Director: Christophe Pillot
- 4 consultants in Paris

HEV, P-HEV and EV market 2011-2025
Impact on the battery business

13 ELBC
PARIS
25-28 SEPTEMBER 2012

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The Rechargeable
Battery market
21st Edition

Customized
survey
METHODOLOGY: EXTENSIVE FIELD RESEARCH TO RETRIEVE & CROSS CHECK INFORMATION

Top management contacts network
> 17 000 contacts

Conferences & Exhibitions

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In Depth analysis Of applications

Cross Check Analysis

Battery Makers

Battery Users, OEM

Substitution technologies: SuperCap, Fuel cells

Safety

Raw materials suppliers

Environment & recycling
Impact on the battery

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2011-2025

MORE THAN 180 REFERENCES WORLDWIDE

A123
AIR LIQUIDE
AIR PRODUCT
AHLSTROM
ALCATEL
AMPEREX (ATL)
APPLIED MATERIALS
AROS SECURITIES
ARC
ASHLAND
ATOFINA - ARKEMA
AT KEARNEY
AXEON
BAIN
BASF
BATTERY R&D ASSOCIATION OF KOREA
B&G
BHP BILLITON
BRAND LICENCING PARTNERS (BLP)
BOURNS
BOSCH
BUHLER GMBH
BYD
CAP X
CATELLA
CARBONE LORRAINE
CARLYLE
CATELLA
CATERPILLAR INC.
CDN COBALT
CEA/LITEN
CELGARD
CHEMETALL
CHEMISHE FABRIK BUDENHEIM
CIBA
CIAPS CHINA
COGEMA
CONOCO PHILIPS
CRU GROUP
CSC CHALLENGE STRATEGY CHANGE
DCN
DELTA
DGA
DIALOG SEMICONDUCTOR
DOW CHEMICAL
DOW CORNING
DUPONT
DURACELL
EDF
ENERGY ONE
ENERGIZER
EOLITE
EPICOS OHG
ERAMET
ETC AB
FACOM
FALCON BRIDGE
FAIRCHILD SEMICONDUCTOR
FAEMART
FIST
FLORIDEENNE DE CHIMIE
FMC
FORTU POWER CELL
FRANCE TELECOM
FULTON INNOVATION
GAIA
GIL IMPORT BATTERIES LTD.
GS MELCOTEC
HC STARCK (BAYER)
HILTI
HITACHI MAXELL
HOLLINGSWORTH & VOSE CIE
HONEYWELL
HPL (HIGH POWER LITHIUM)
HUTCHINSON
IER
IGL EXPORT.
INTERMEDIATE COMPONENT CORP.
INTERNATIONAL RECTIFIER
INTEK
INTEL
INTERSIL
INCO
ITRI
ITS
JBC
JETRO
JOHNSON CONTROLS
KODAK
KRUGER
LAZARD
LECLANCHE
LEGRAND
LG CHEMICAL
LION CELLS
LITTLE FUSE
LILIPUCIAN
LYNAS CORP
MATSUURA
MICROSOFT
MTI MICRO FUEL CELLS
MOLTECH
MOLYCORP
MOMENTIVE
MOTOROLA
MUNSTER UNIVERSITY
NANOCYL
NCCP - RUSSIA
NITECH
NKKPC
NORILSK NICKEL
NOVALED
NTK POWERDEX
OMG INC
PANASONIC
PHILIPS
PHOTON
PK & WISE
POWER GENIX
PRAVATON
PRISMARK
PSA
RAYOVA
RECHARGE
RENAULT
RHODIA
ROLAND BERGER
SAFT
SAGENTIA
SAINT GOBAIN
SAKTI
SAMSUNG SDI
SANIK
SCHRODER VENTURE
SCOTENT ENTREPRISE
SFPZ
SHENZHEN HIGH POWER TECHNOLOGY
SCHOTT AG
SKC
SVE - DASSAULT
SOLVAY
SONY
STIBAT
STORCK
STRATEGY ANALYSIS
TERRAROSSA CAPITAL
TIGER GLOBAL
TODA KOGYO
TOTAL
TOTAL WIRELESS SOLUTION
TOYOHASHI UNIVERSITY
TOYOTA
TYCO
UMICORE
UNIROSS
URALALEMENT
US NAVY
VARTA
VOLTRACK
WARBURGPIRCHER
WORLD INDUSTRIAL INFORMATION CENTER
WR GRACE & CIE
YASLAMEN
ZEBRA
ZPOWER

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AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2011

EV sold, in million units, worldwide, 2010 - 2020

OUTLINE

THE RECHARGEABLE BATTERY MARKET IN 2011/2012

THE HEV, P-HEV & EV MARKET IN 2011/2012

2020 FORECASTS

IMPACT ON THE BATTERY BUSINESS

IMPACT ON THE LED ACID BATTERY BUSINESS

CONCLUSIONS
THE WORLDWIDE BATTERY MARKET 1990-2010

Lithium Ion Battery: Highest growth & major part of the investments

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- Lead acid batteries: By far the most important market (90% market share)

THE WORLDWIDE BATTERY MARKET 1990-2010

- Lithium Ion Battery: Highest growth & major part of the investments
- Lead acid batteries: By far the most important market (90% market share)
THE WORLDWIDE BATTERY MARKET 1990-2010

Lead acid: Major market

<table>
<thead>
<tr>
<th>Year</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>100 000</td>
</tr>
<tr>
<td>2000</td>
<td>150 000</td>
</tr>
<tr>
<td>2010</td>
<td>300 000</td>
</tr>
</tbody>
</table>

- **Lithium Ion Battery**: Highest growth & major part of the investments
- **Lead acid batteries**: By far the most important market (90% market share)
- **Lead acid**: Major market

**Graphs**:
- **THE WORLDWIDE BATTERY MARKET 1990-2010**
- **Impact on the battery business**

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**Event Details**:
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THE WORLDWIDE BATTERY MARKET
1990-2010

35 BILLION US$
5% AVERAGE GROWTH PER YEAR (1990-2010)
## EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES

<table>
<thead>
<tr>
<th>Advantage of</th>
<th>Lead Acid</th>
<th>Nickel Cadmium NiCd</th>
<th>Nickel Metal Hydride NiMH</th>
<th>Lithium-Ion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gravimetric energy density</td>
<td>Volumetric energy density</td>
<td>Operating temperature range</td>
<td>Gravimetric energy density</td>
</tr>
<tr>
<td></td>
<td>Operating temperature range</td>
<td>Self discharge rate</td>
<td>Gravimetric energy density</td>
<td>Volumetric energy density</td>
</tr>
<tr>
<td></td>
<td>Self discharge rate</td>
<td>Reliability (progressive extinction)</td>
<td>Gravimetric energy density</td>
<td>Volumetric energy density</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>• Higher cyclability</td>
<td>• Voltage output</td>
<td>• Price</td>
<td>• Higher cyclability</td>
</tr>
<tr>
<td>Nickel Cadmium NiCd</td>
<td>• Operating temperature range</td>
<td>• Higher cyclability</td>
<td>• Price</td>
<td>• Operating temperature range</td>
</tr>
<tr>
<td>Nickel Metal Hydride NiMH</td>
<td>• Price</td>
<td>• Safety</td>
<td>• Recyclability</td>
<td>• Price</td>
</tr>
<tr>
<td>Conventional</td>
<td>• Operating temperature range</td>
<td>• Higher cyclability</td>
<td>• Price</td>
<td>• Operating temperature range</td>
</tr>
<tr>
<td>Laminate</td>
<td>• Price</td>
<td>• Safety</td>
<td>• Recyclability</td>
<td>• Price</td>
</tr>
<tr>
<td>Absolute advantages</td>
<td>• Price</td>
<td>• Operating temperature range</td>
<td>• Higher cyclability</td>
<td>• Price</td>
</tr>
<tr>
<td></td>
<td>• Operating temperature range</td>
<td>• Higher cyclability</td>
<td>• Price</td>
<td>• Volumetric energy density</td>
</tr>
<tr>
<td></td>
<td>• Price</td>
<td>• Volumetric energy density</td>
<td>• Self discharge rate</td>
<td>• Voltage output</td>
</tr>
<tr>
<td></td>
<td>• Volumetric energy density</td>
<td>• Voltage output</td>
<td>• Lower discharge rate</td>
<td>• Gravimetric energy density</td>
</tr>
</tbody>
</table>

### Lead Acid
- Higher cyclability
- Voltage output
- Price
- Reliability (progressive extinction)

### Nickel Cadmium NiCd
- Operating temperature range
- Higher cyclability
- Self discharge rate
- Price

### Nickel Metal Hydride NiMH
- Operating temperature range
- Higher cyclability
- Price

### Conventional
- Operating temperature range
- Higher cyclability
- Price

### Laminate
- Operating temperature range
- Higher cyclability
- Price

### Absolute advantages
- Operating temperature range
- Higher cyclability
- Price
WHY X-EV?

Petroleum consumption worldwide 1960-2030

Price of the WTI barrel of oil, US $

CO2 density in the atmosphere increase

Source: Energy Information Administration, US Government

Source: http://www.eia.doe.gov/emeu/steo/pub/contents.html

Source: IPCC, Intergovernmental Panel on Climate Change, Climate Change 2007, Synthesis Report p38
HEV, P-HEV & EV MARKET
DEFINITION & SEGMENTATION

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HEV, P-HEV and EV market 2011-2025

Fuel saving Vs. Cost

EV
P-HEV
HEV
HEV WORLDWIDE IN 2011
LESS THAN 0.9M HEV SOLD

HEV sold per year, M units, worldwide, 2000 - 2011

Penetration of hybrids in the global sales, 2000-2011

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included
HEV WORLDWIDE IN 2011
BY CAR SUPPLIER

Total HEV Vehicles
Less than 0.9 M in 2011

HEV sold per year, M units per car manufacturers, 2000-2010

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included
HEV WORLDWIDE IN 2011
BY CAR SUPPLIER

TOP 3: TOYOTA, HONDA, HYUNDAI

OTHERS: FORD, MERCEDES, GM, NISSAN…

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE… Compilation AVICENNE ENERGY
Micro hybrid not included
HEV WORLDWIDE IN 2011
BY COUNTRY

Total HEV Vehicles
Less than 0.9 M in 2011

- USA (31%)
- JAPAN (48%)
- EUROPE (14%)
- OTHERS (7%)

HEV sold per year, M units per country, 2004-2011

USA
JAPAN
EUROPE
OTHERS

Micro hybrid not included
HEV FORECASTS 2011-2020

HEV MARKET: 2 Million units in 2015 & 4 M Units in 2020

Micro hybrid not included
LONG TERM HEV FORECAST FROM 3 TO 8 M HEV IN 2020

AVICENNE ENERGY FORECASTS ARE REALISTIC COMPARE TO OTHER ANALYSTS

Source: AVICENNE ENERGY Compilation, February 2012
Micro hybrid not included
LI-ION PENETRATION IN VARIOUS DEVICES: AVICENNE & OTHER ANALYSTS FORECAST

Li-ion penetration in electronic devices & HEV

HEV powered by LIB forecasts from 2008 to 2011

(1) AVICENNE HEV Forecasts, march 09, Relevant scenario
(2) AVICENNE HEV Forecasts, march 09, Li-ion Optimistic scenario
(3) IIT, TAKESHITA, March 08, THE 25th INTERNATIONAL BATTERY SEMINAR & EXHIBIT, Slide 8 & March 2009, 26th Battery Seminar,
(4) AAB, Menahem ANDERMAN, Ph.D, Tampa, Florida, May 2009


Micro hybrid not included
LIB BUSINESS
RECALL SLASH BATTERY PROFIT

- More & more incidents & accidents
- All the battery makers and the OEM are concerned
- Recall cost impact drastically the battery business and the profitability

<table>
<thead>
<tr>
<th>Battery Makers</th>
<th>OEM</th>
<th>Battery recall</th>
<th>Date</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matsushita</td>
<td>Nokia</td>
<td>46 M cells</td>
<td>08/07</td>
<td>170 MUS$</td>
</tr>
<tr>
<td>Sanyo</td>
<td>Mitsubishi</td>
<td>1.3 M cells</td>
<td>12/06</td>
<td>35 MUS$</td>
</tr>
<tr>
<td>Sony</td>
<td>Dell, Apple, Toshiba, Lenovo, ...</td>
<td>10 M Packs 65 M cells</td>
<td>2006</td>
<td>430 MUS$</td>
</tr>
<tr>
<td>Sony</td>
<td>HP, Toshiba, Dell</td>
<td>0.44 M</td>
<td>2009</td>
<td></td>
</tr>
</tbody>
</table>

Operating profit/Revenue

Sanyo
MBI
BYD
SGS
Sony
NEC
Maxell
LGC
SDI
Average
TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY

The research and development in this industry is very long and time consuming.

Time to market to commercialize a new material is long. Remember that the first Li-ion battery was launch by Sony in 1991 with LCO cathode, graphite, LiPF6 electrolyte & polyolefin membrane. It was 20 years ago.

LTO was invented by Matsushita in 1993 (19 years ago)

Lithium iron phosphate was invented in 1995 (15 years ago).

So, it take between 10 & 20 years to commercialized a new material in the battery industry.
LIB MANUFACTURING INVESTMENTS 2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

Total Investment (M$) made for LIB manufacturing

- LiTec GmbH
- Panasonic EV
- SK Energy
- Mitsubishi H.I.
- NEC Tokin (Electrodes)
- AESC Japan
- Hitachi Vehicle Energy
- SAFT
- SAFT US
- BAK
- Lishen
- Nissan-Renault (Port)
- Blue Energy
- Toshiba
- Nissan - Renault (UK)
- LG Chem - Compact...
- Rusnano-Thunder Sky
- Lithium Energy Japan
- Hitachi Vehicle Energy
- SB Limitative
- GS YUASA
- Dow Kokam (KD ABG MI)
- Nissan-Renault (Fr)
- Ener1
- Sanyo
- A123
- JCI
- LG Chem
- BYD
- Sony
- NISSAN Motor US
- PANASONIC

Average Investments: 250 $ / kWh

A123 Michigan Plant - Photo courtesy of A123 Systems

Liotech Plant, Novosibirsk – 1,5 GWh production capacity
LIB BATTERY COST

Costs analysis

- Raw material cost (Co, Mn, Ni, Al, Cu, ...)
- Anode, cathode, Electrolyte, separator, binders, Cu & Al foil, etc...
- cost structure:
  - CAPEX
  - labor cost
  - R&D
  - Marketing, Adm, Overhead, margin)

- Raw material needs / mAh
- Electrode process Yield
- Assembly Process Yield
- Cell manufacturing cost
- Module manufacturing cost
- Pack assembly cost
- ...

Battery price in 2011
$/kWh
LI-ION BATTERY COST
2011-2020

LIB cell average cost
(EV design ; NMC cathode)

LI-ION BATTERY PACK COST
FOR EV

* For Production > 100 000 packs/year
## EV FORECASTS 2011-2020

**EV sold, in million units, worldwide, 2010 - 2020**

<table>
<thead>
<tr>
<th>Year</th>
<th>Mobile Phone</th>
<th>Portable PC</th>
<th>Power Tools</th>
<th>E-bikes</th>
<th>HEV</th>
<th>P-HEV</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>4</td>
<td>50</td>
<td>45</td>
<td>400</td>
<td>1000</td>
<td>10000</td>
<td>25000</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average Wh per device**

- Mobile Phone: 4
- Portable PC: 50
- Power Tools: 45
- E-bikes: 400
- HEV: 1000
- P-HEV: 10000
- EV: 25000

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**Impact on the battery business**

- HEV, P-HEV and EV market 2011-2025
- IIT (March 2010) Fort Lauderdale
- Deutsche Bank, Electric Cars: Plugged In 2 – Nov 2009
- Roland BERGER, Oct 2011, Batteries 2011 Cannes
- AAB, AABC Europe, Mainz, June 2011

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TOTAL BATTERY DEMAND
2011-2020

EV, HEV & P-HEV Battery needs (M Wh) 2005 – 2020

Total battery demand (MWh) 2000 – 2025

- NiMH for HEV
- LIB for HEV
- LIB for P-HEV
- LIB for EV

NiCd
NiMH except Auto
LIB except Auto
NiMH for HEV
LIB for HEV
LIB for P-HEV
LIB for EV

HEV, P-HEV and EV market 2011-2025
Impact on the battery business
35 MILLION MICRO-HYBRIDS CAR IN 2020

Micro-hybrids car market 2010-2020

Advantages of micro-hybrid compare to HEV

- Powered by Advanced lead acid batteries
- Much more profitable than full HEV: 8 to 10 times less expensive than full HEV to save 5% gasoline instead of 20% (4 times less)
- Much more impact on CO2

<table>
<thead>
<tr>
<th></th>
<th>Micro-hybrid</th>
<th>Full HEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>Advanced lead acid</td>
<td>NiMH or LIB</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>300</td>
<td>3000</td>
</tr>
<tr>
<td>Fuel saving</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>Million Vehicle sold per year in 2020</td>
<td>35</td>
<td>3.5</td>
</tr>
</tbody>
</table>
HEV, P-HEV AND EV REALITY OF THE MARKET WILL BOOST MICRO HYBRID AND ADVANCED LEAD ACID BATTERIES

<table>
<thead>
<tr>
<th>Year</th>
<th>STANDARD CAR</th>
<th>MICRO HYBRIDS</th>
<th>MILD HEV</th>
<th>FULL HEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>88.5%</td>
<td>10%</td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td>Advanced Lead acid (+ EDLC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>54%</td>
<td>MICRO HYBRID 40%</td>
<td></td>
<td>FULL HEV 4%</td>
</tr>
</tbody>
</table>

AFTER

- ULTRA BATTERY
- Li-ion
- Li-Air, Li-S, Fuel Cells
TAKEAWAYS

Battery Market 2010-2020
CAGR = +8%

- Li-ion battery is driven today by Portable PCs & electronic devices
- For HEV, the battery technology is today the NiMH
- LIB begin really to compete in 2012
- P-HEV & EV will be powered by Li-ion: 5 B$ market in 2015 & 9 B$ in 2020
- EV expectations attract large Chemical companies
- New materials are needed to meet Automotive standards
- HEV will account for less than 5% of the automotive sales in 2020
- P-HEV & EV < 2% by 2020
- Micro-hybrid will achieve 40%
- Lead acid battery will be the first market in 2020 in volume & value

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THANK YOU

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